Nepal Engineering College

Batho Chulho

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BATHO chulho

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1. Abstract

The socio-economic divide has unfortunately led to yet another threat called the digital divide. The latest development in computer science is biased to industrialization and sophistication providing an expensive solution to a problem often failing to address the primary requirements of the society. In an effort to improve the living standard of the poor, several developmental organizations have developed and promoted the use of energy efficient- environment friendly cook-stoves using wood-fuel. But ***Batho Chulho***[1] is a step-ahead of all such efforts in the sense that the presented model is the only computerized wood fuel burning cook-stove ever developed.

Use of wood for cooking is the biggest cause of deforestation throughout the world. Deforestation in turn is a major cause of environmental degradation. Wood is considered to be a renewable energy in the sense that the loss due to consumption can be compensated by plantation. But that has not been the case so far and deforestation is increasing at an alarming rate.

Again to the negative consequences of forest wood as a fuel, the smoke produced directly could be a great health hazard. As a matter of fact it can be easily conceived that improper use of firewood have several short term and long-term effects directly imposed to the society where there is no way out. Short term effects like indoor pollution accounts in emission of Acrolein, CO, HCHO, NO_X , Particulate, PAHs, VOC and countless other poisonous substances resulting in Health hazards including eyes and respiratory tract irritation, heart diseases , bronchial congestion, lung edema etc. moreover these substances are also carcinogenic

In this project, we explored the possibility of using wood effectively for cooking so that deforestation could be retarded as well as indoor air pollution is minimized. We come up with a computerized cook-stove that burns briquette in a smart way to minimize the fuel consumption. Apart from being fuel efficient, the present system also offers several ease-of-use features that enhance the chances of its acceptance in rural communities where traditional cook-stoves are an integral part of the culture. As the system is designed in a modular fashion rather than designing a single basic model, the system can be configured according to the budget and other relevant factors. Versatility has been a key concept in designing the system and therefore not only the system is versatile (one can configure it) but with the use of the system, cooking process becomes more versatile (one can adjust burning rate and time-to-burn). Thanks to the embedded computer.

[1] *Batho Chulho* means Smart Cook-stove in Nepalese and is Pronounced : /bɑːʈʰəoː tʃuːlou /

2. System Overview

Batho Chulho is a briquette fueled cook-stove integrated with an embedded system that functions so as to make the cooking process more fuel-efficient and less time consuming. It is equipped with sensors that measure the heat rate generation and actuators that control the combustion process. The embedded system incorporates control routines that make the system smart. Before going into the implementation details of the system, we present the requirement analysis of the system.

2.1 System Requirements Analysis. Initially, the following requirements were formulated for the system:

a. The system should offer better fuel efficiency than existing wood-fire cook stoves.
b. The product price should be reasonably low so that rural communities can afford it.
c. The cooking system parameters like rate of heat generation should be user adjustable.
d. The design should offer interactivity that is meaningful in rural context.
e. The power supply for the control system should be derived locally.
f. The initial ignition system should preferably be started with one-touch operation.
g. The combustion should halt immediately after the user commands the system to do so.

2.2 Design Methodology. ***Batho Chulho*** is a combination of research, hardware, and software with some mechanical designs. The team members were assigned jobs according to their matching interests and expertise. As the team members lacked expertise in cook-stoves, they consulted several experts of the field. The result was the selection of the briquette fuelled cook-stove as the platform for adding the computational features. In order to find suitable development model for our case, we chose Rapid Application Development model and modified it according to our own requirements. Before starting the parallel development we worked together to have extensive study on the field for modeling. And then the tasks were divided and pipelined with independent models and deadlines. While the mentor supervised all the parallel works and did the formal technical review of the project. Each module was intensively tested separately before the integration and final testing.

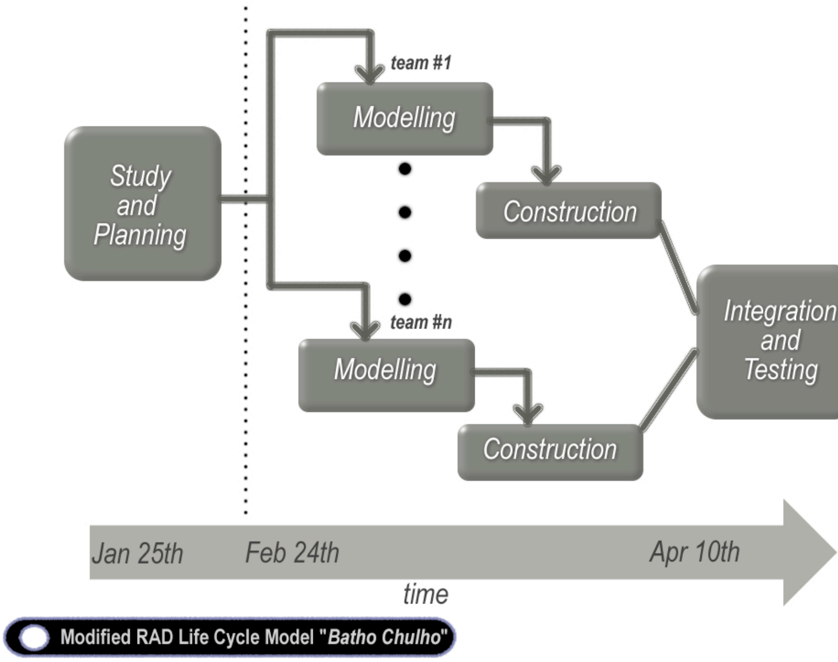

Fig 2.1: Modified RAD Model Used for Batho Chulho Development.

2.3 Innovation. Engineering is not just about developing a good gadget but it is about designing an appropriate solution for real world problems. Keeping this in mind, ***Batho Chulho*** has been designed to address the multidimensional scope of the problem. We claim that the project is first of its kind. The project not only helps to protect (by minimizing the production of air contaminants during combustion) and preserve (by increasing the cooking efficiency, it helps to minimize deforestation) the environment but also helps to improve the livelihood of the rural community. Even though hundreds of researches have been done and many final designs are prescribed for fuel-efficient, eco-friendly wood fire cook-stoves, they have not reached the end-user at desirable volume. The main reason is their complexity of operation, economical feasibility and appropriateness. If the proposed solutions were able to hive the user friendliness and appropriateness virtually there was no need to design any stove whatsoever. This study helped us to visualize our problem domain clearly.

2.4 Project Impact. The project *Batho Chulho* plays a significant role in environmental protection and preservation due to the fact that:

i. As fire-wood is relatively easily available locally and cost effective as well most of the lower-middle and lower class people, which comprises a significant world population, cook on fire-wood. Thus even a slight improvement on the traditional technology and efficient use of wood make a significant impact in the global environmental scenario.

ii. Burning briquette, a processed form of wood-fuel, is much more energy efficient than burning the wood directly and emits much less environmental pollutants like CO. Moreover, it can be easily obtained from wood in the rural areas. Despite all this benefits, briquette cook-stoves have not been able to displace the traditional wood-fire cook-stoves as people hesitate to change their ancient cooking-culture. ***Batho Chulho*** uses briquette as fuel and at the same time provides a set of easy to use features (like combustion control, auto-ignition and timers). These additional features possible due to the integration of computational module encourage the users to abandon the traditional cook-stoves and use much more fuel-efficient technology thereby decreasing the rate of deforestation.

iii. Several studies on improving the cooking-efficiency conclude that the efficiency of a cook-stove ultimately depends on the cooking-habit of the user. Since the burning of the briquette is not controlled in traditional stoves it results in waste of energy produced on situations like low energy requirements and cooking intervals. The energy also goes waste after the cooking is over as the combustion continues until the existing supply of fuel does not burn out. ***Batho Chulho*** provides smartness to the cook-stove and provides abstraction to the user. As a result, the cooking-efficiency of the stove is no more user-dependent.

iv. Due to the ease-of-use features integrated in *Batho-Chulho,* the system demands very little attention from the user and thus the user can keep themselves busy with other jobs while cooking. As women are the user in most of the cases, they will be able to save some time for other tasks like nurturing their children or being involved in some sort of income generating activity. This way, the use of ***Batho Chulho*** helps to improve the livelihood of the people.

The effort to minimize wood consumption is therefore important for conservation of the environment, which can be easily incorporated by efficient use of briquette. Our goal is to study existing improved cook-stoves to select the best design and add computer components making cook-stove smart enough to control the system achieving results discussed above.

3. Implementation and Engineering Consideration:

3.1 System Overview. The ***Batho Chulho*** comprises of several modules working together. At a glance the general glimpse of the system is as in figure below.

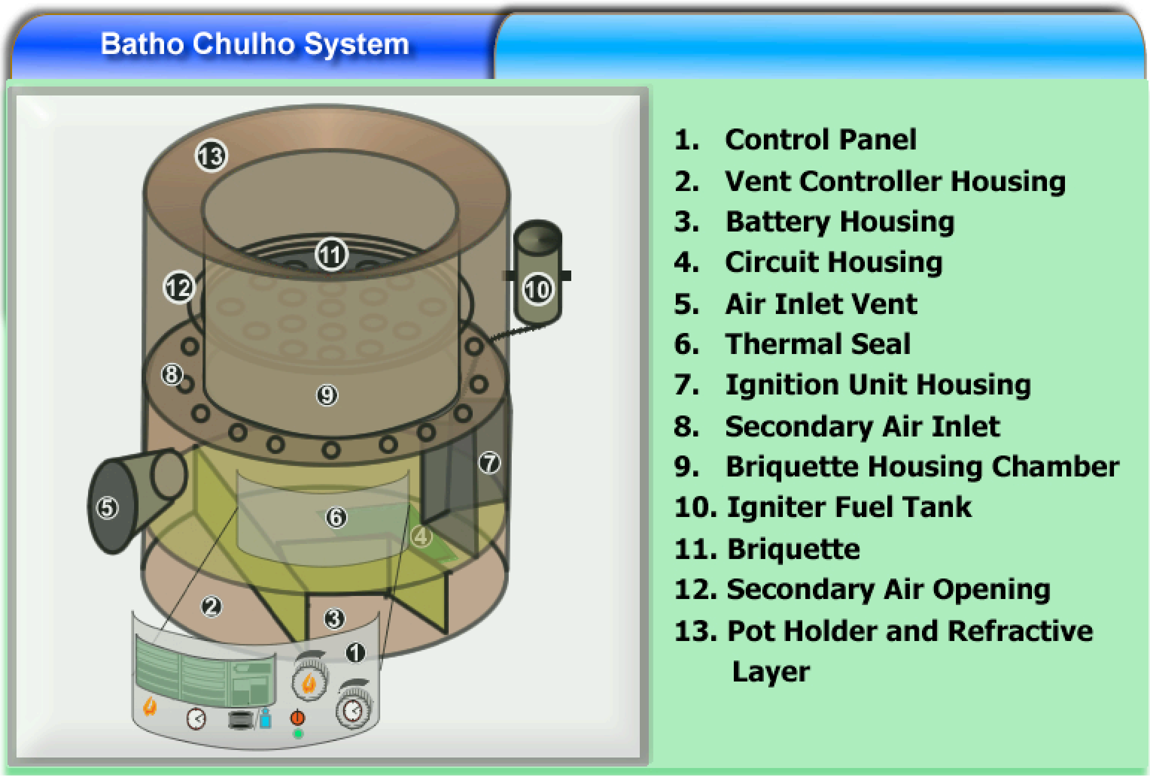

Fig 3.1: General Diagram of *Batho Chulho* System.

The base of the system consists of the embedded system circuitry. This arrangement appears to contradict the natures' principle of placing the mind in the top. The arrangement is preferable for the reason that the bottom of the cook-stove can be easily isolated from the heat in the cook-stove. The basement chamber consists three housings for circuit, power supply and air supply vent controller.

The most of the free space resides inside the second part, which is the primary air flow chamber. We have placed the control and display panel outside this chamber because it requires the most of wiring with system core unit and this is the region most visible and accessible. At the mean time this region is also isolated from the heat produced during combustion. As the chamber consists two of the most important parts, i.e. primary air flow unit and the ignition unit, we name this chamber as the primary chamber.

The primary chamber is roofed by the briquette holder. Then there comes the briquette housing chamber. The inner wall of the chamber above the briquette holder is insulated with a refractory material so that so that the heat produced does not escape via the outer metal cover. The refractory material used is made up of a mixture of clay and ash and the arrangement is called the refractive molding.

Without a defined boundary with the briquette holding chamber secondary burning chamber starts. This is to ensure the design requirement that the secondary burning chamber should have air inlets just over the burning surface to ensure the proper oxidization of hazardous gas like Carbon Monoxide (CO). Outside this chamber there lies the igniter fuel in loneliness as it is not to be in direct contact with outer casing to avoid any chances of accidental ignition due to the heat inside.

At the topmost part of the system, there is a parabolic pot holder with an opening of diameter 14cm in the middle as compared to the standard 13 cm diameter of the briquette. The handle can be attached and covers can be provided for users as per the requirement. Both components are not shown for brevity.

The usual scenario could be explained through a conversation between a general user and novice of a system.

*(It's the evening time and my dad is in the kitchen, my little sister enters the scene. Dad is ready with tea kettle and heading towards "**Batho Chulho**").*

Sister: *Dad will you please teach me how to use this stove.*
Dad: *Why not my dear, come here.*
Sis*: Okay dad, how do you turn it* ***ON****?*
Dad*: This it the trigger, when you press it downward the briquette is ignited inside.*
Sis*: Oh! It sound easy, let me try. (She presses the trigger downward.).Is that all papa.*
Dad*: No my child, you can select the modes to operate and* ***OFF*** *timer.*
Sis*: where is it then?*
Dad*: See, (turn stoves slightly to face Control/display Unit). These two Knobs are adjustable.*
Sis*: wait dad I can easily figure out which knobs is for timer and which is for mode. Wow there is a display unit too. But what are other displays. Do I need them?*
Dad*: Well others display are to see fuel status and you need them because when the status show empty you need to refill them.*
Sis*: Thanks dad it's really a nice stove, and easy to use too.*

3.2 System Modules. The ***Batho Chulho*** design team faced a tough design challenge. The nature of the project imposed three constraints in the design: functionality, cost and appropriateness. A design that is fully functional would cost higher and therefore the product would not be feasible. On the other hand, an auto-ignition system that requires kerosene for initial ignition would not be feasible owing to the fact that kerosene is not readily available in all regions. An intensive survey would be required to workout a tradeoff that would be suitable for all target regions. Even then, the design would be a compromise in terms of functionality. Therefore, instead of working out a specific design, a modular approach was adopted. Under this design principle, each subsystem of the system is considered to be an independent module. A module will have its own functionality, cost and appropriateness associated with it. Based on these three measures, a module will be classified as '*Required*', '*Optional*' or *'Not Required'*. A *Required* module is that which provides functionality worth the cost of the module and at the same time is appropriate in all target regions. The combustion control module is an example of a *required* module as it is the module that makes the system fuel efficient at considerable cost. The kerosene based initial ignition system on the other hand is an *Optional* module for the reason that unavailability of kerosene in some

reasons make it inappropriate for those reasons and thus the module can be omitted. The table below summarizes the classification of all modules of ***Batho Chulho***.

Table 3.1: General Classification of Modules of *Batho Chulho.*

Functionality	Cost	Appropriateness	Classification
Combustion Control	Medium	Appropriate	***Required***
Automatic Ignition	Medium	Conditional (due to unavailability of ignition fuel)	***Optional***
System Timer	Low	Appropriate	***Required***
Alphanumeric Display	Low	Conditional (due to illiteracy)	***Optional***
Automatic briquette feeding	High	Appropriate	***Not Required***

Batho Chulho system has been designed keeping in mind the above facts considerations. The UML approach has been used as far as possible for efficient design and presentation of the system.

3.3 User Interaction. Since the system is targeted for the poorer half of the world population, usually with less or no education, the user interaction should be trivial rather than instructive. Next benefit of using this approach is that the time needed for overall operation is drastically minimized so that the time could be utilized some something more productive. User attention is necessary only at four incidents in the entire usage cycle. The scenario for user interaction is easily explained using the use case diagram that follows.

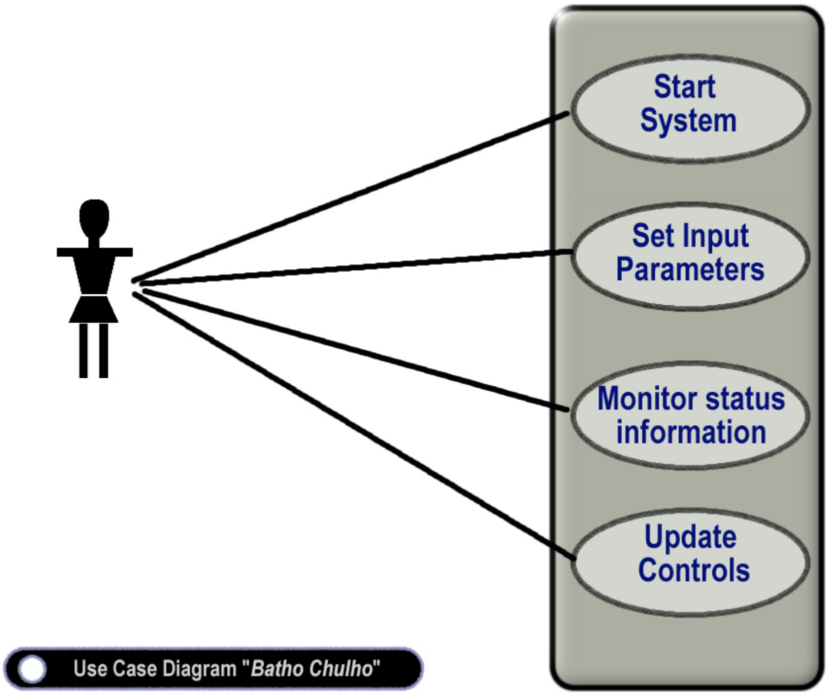

Fig 3.2: Use Case Diagram of *Batho Chulho.*

Initially user starts the system by pressing a trigger button and initializes the input parameter considered for cooking using the control panel. Sometimes, the user may have to monitor the system to insure that task given to the system is accomplished or not. Generally, it involves the length of time preset by user for the system to operate. The user also may interact with system in order to change the required parameter afterwards during the use. Typically, this may be the case when user wants to switch from one mode to other or the case when accidentally user initializes wrong input parameters. Besides, there is status information provided to user so the necessary operation could go smoothly. That status information may include the status of primary, secondary fuel or power supply indicators. If the steps explained above are duly fulfilled by a particular user the system is guaranteed to run seamlessly.

3.4 System architecture. The easiest way to model a system is to find out the systems and subsystems it consists of. In our system we have used the deployment diagram of UML approach to relate every subsystems and units in hierarchical and relational order.

The main system core works with system control core and user input subsystem. By its name we can depict what the system really does. System control core is the core hardware and contains actual functional mechanism of cooking and efficient control of cooking. Even though this system interacts actively with user input subsystem that is only a communication consideration handled through a mediator which is exactly the parent of these two systems which in this case is a microprocessor incorporated.

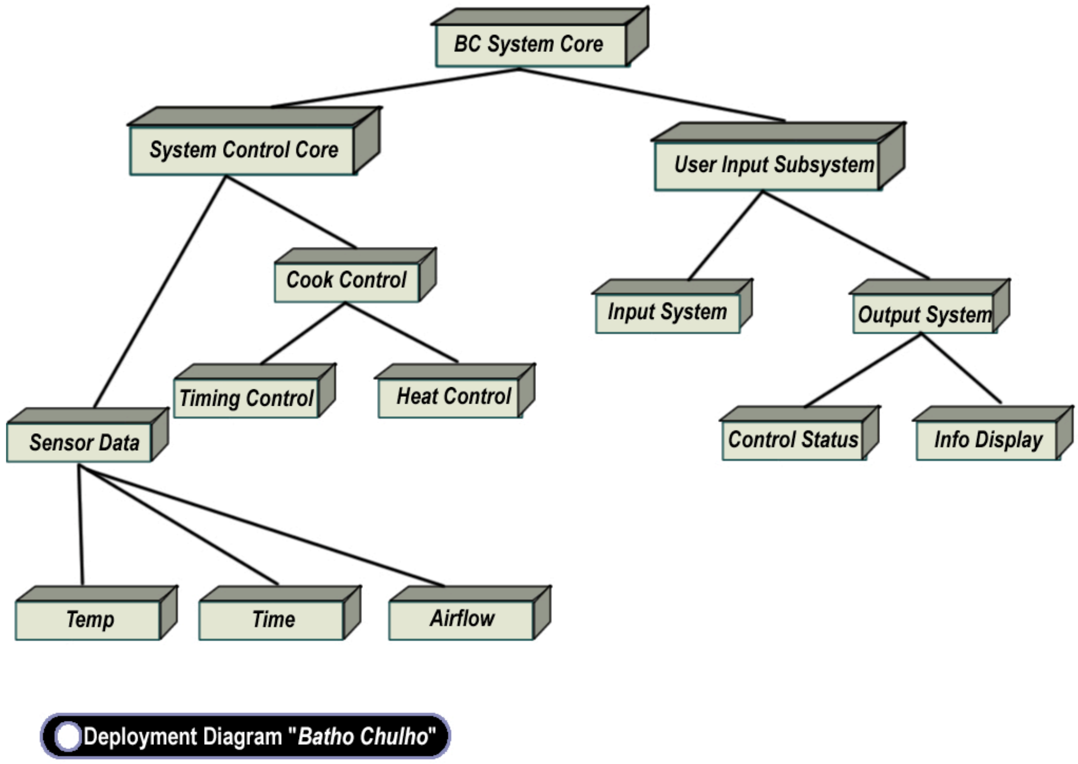

Fig 3.3: The Deployment Diagram of *Batho Chulho*.

The system control core could be actually divided into two halves as represented in diagram below. The cook control unit and sensor unit. The coordination between these two units is done through the database stored at memory location at the instant of operation. The cook control unit utilizes the data in order to effectively run the system as per user settings. The databases are updated in real time basis. In our system we have actually used three basic sensing mechanisms for temperature, time and airflow respectively.

Similarly cook control unit consists of timing control and heat control subunits. Timing control is a function of the relation between the user input settings and software which keeps the updated timing data of the system operation. The main function of this unit is to control system uptime.

The heat control directly associates itself with mode of operation set by user and current temperature of the cooking system sensed by the sensor unit. Its main function is to maintain the defined temperature by controlling the primary air flow.

The user interaction subsystem has input and output systems. The user settings are actually received by this unit which is the basis for the main system functionality. The output subsystem is mainly intended to pass the message to user about actual control status and the status of the inputs the user is giving to the system. It is the role of user to coordinate between these systems.

3.5 Hardware Unit.

3.5.1 Briquette is the primary fuel of the ***Batho Chulho***. So a brief description is given here. Briquette is made up of grinded charcoal banded with some binding material in a cylindrical shape with 19 holes in it. It is 13cm in diameter and about 7cm in height which makes its weight to about 400gms when soil is used as binding material in 4:1 ratio. A typical briquette lasts for about 2 hrs. This is about twice the average cooking time for a family of five. The briquette could be easily constructed manually using a mould and hence could be easily manufactured at a large scale industrially.

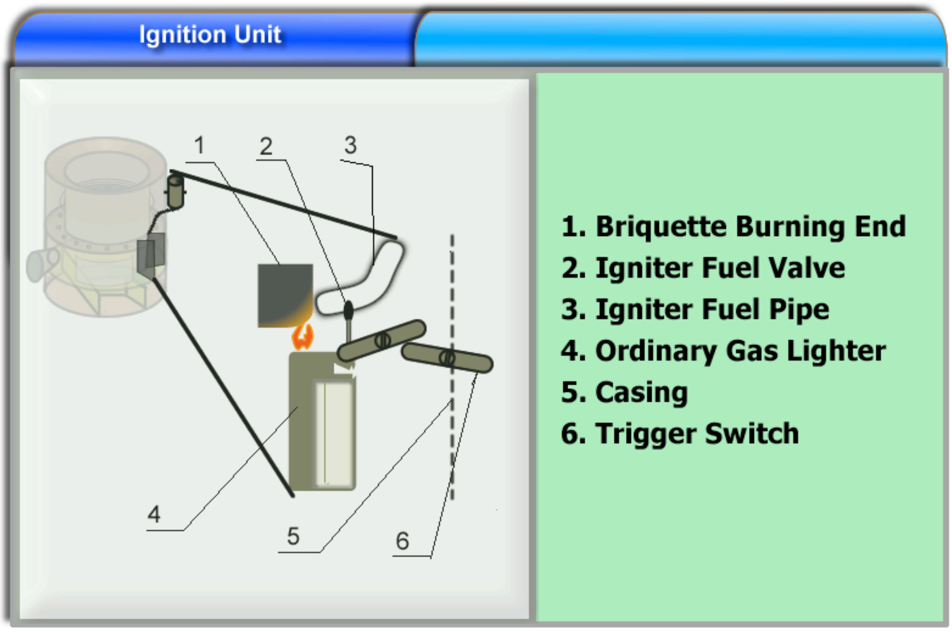

Fig 3.4: The Ignition Unit of *Batho Chulho*.

3.5.2 Ignition Unit has two functionalities, one is to start the ignition of the briquette and the other is to switch on the system. This is done by a trigger switch which is mechanically connected with igniter fuel valve and the primary igniter. The primary igniter is a locally available gas lighter. In case of unavailability of the gas lighter users can directly ignite with any other means of fire like match sticks. When the trigger is switched it switches on the system in the meantime it also opens the valve of the ignition fuel, which is kerosene in a tank attached with the stove. There is such a mechanism that the fuel soaks the briquette which is then ignited with the igniter.

3.5.3 Airflow Vent Control Unit controls the heat of the stove by controlling the burning rate of the briquette. The burning rate is controlled by controlling the air flow inside the burning chamber. There are two types of air flow namely, Primary air and Secondary air. The inlet for both types of air supply is the same. From the chamber some holes have been made up to the upper end of the briquette to supply the secondary air. So, both of the air supplies are controlled through the same vent control. The airflow vent is completely software controlled. The controlling software uses the fuggy engine. The fuzzy engine takes data from temperature sensor and the current vent status as input and output for vent controller for desired status as output. The more about it is explained in software part.

The software directs the rotation of the motor unit which rotates the butterfly vent from 0% opening to 100% opening with discrete angles. The system is explained in figure below. The shape of the air inlet ensures the efficient flow of the air into the chamber, which is then supplied to primary and secondary burning of the briquette. To burn the briquette in maximum rate the vent is completely opened and to extinguish it the vent is completely closed. The principle is as simple as that the air, Oxygen being specific, is responsible for the burning of the briquette. So the intermediate openings control the rate of burning controlling the heat energy at the base of the pot. The vent opening is controlled by the software in the microcontroller ordering the stepper motor to rotate in the required steps.

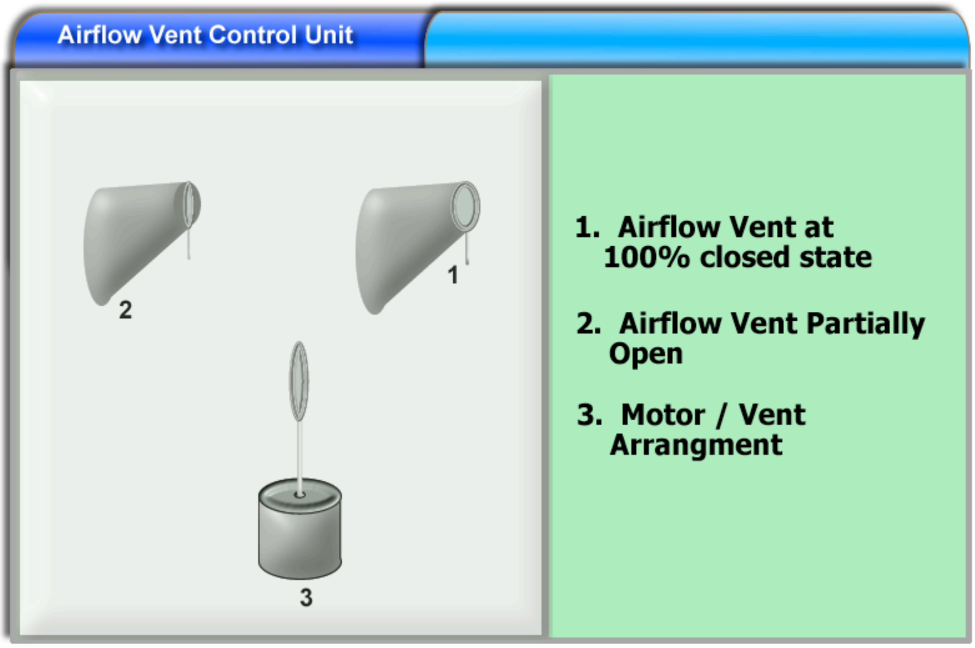

Fig 3.5: The Airflow Vent Control of *Batho Chulho.*

3.5.4 Control Panel/ Display Unit which we also used to call UI unit (User Interface) is the unit to interact with the user. Control panel consists of simple control knobs each for controlling cook mode and time. When the knobs are turned clockwise the respective values are incremented and vice versa. Simple potentiometer and ADC circuits have been implemented to get the user values up to the system core. The GUI of the system consists of a LED and LCD panel. LCD panel is divided into three sections. First section shows the current mode in increasing amount of heat to be produced by the system. And second section shows the desired system uptime settings. Which gradually decreases as the time passes by. Both of them show the fuzzy levels. The purpose of LED is as simple to glow when the system is ON and working.

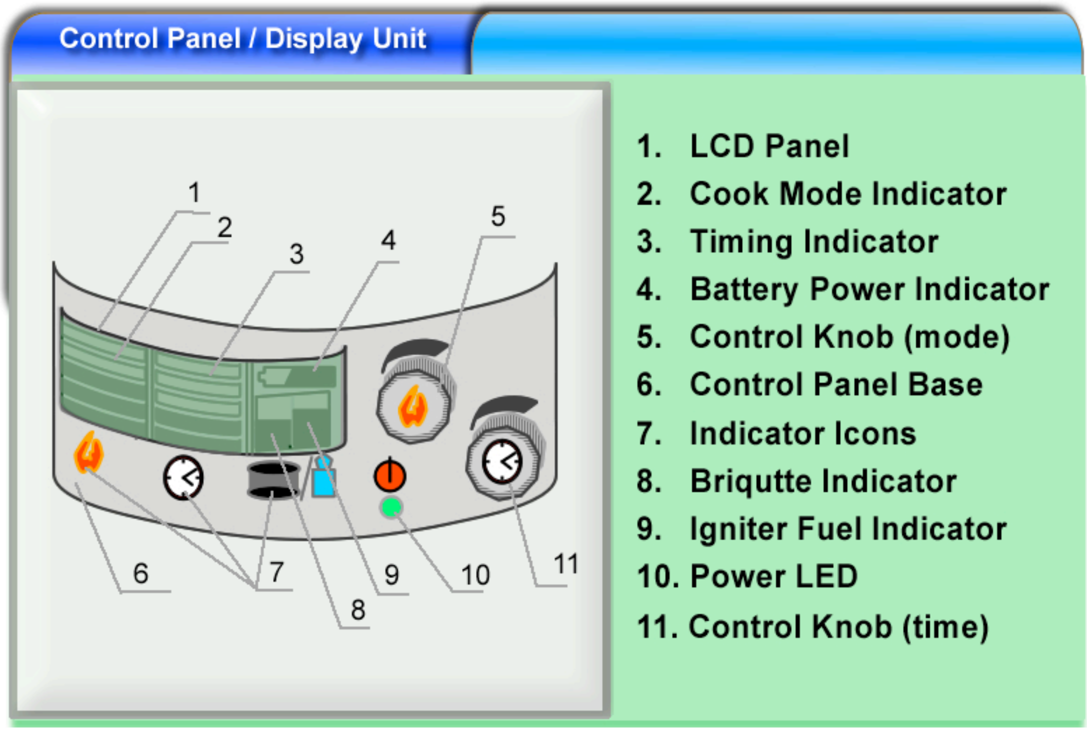

Fig 3.6: The Control Panel and Display Unit of *Batho Chulho*.

The third section shows the fuel status and battery power. The briquette status is shown with the help of counter which stores in second the time from which a new one is inserted and the level is decremented knowing that typical briquette lasts for about 2 hours during normal operation. The mechanism for showing igniter fuel level is a small system designed by one of our enthusiastic junior using simple level sensor. Battery status is also shown in the right top corner of the display unit as shown.

3.5.5 Circuitry and Power Supply. ***Batho Chulho*** uses AT89C55 microcontroller as the central processing and controlling unit in coordination with ADC0808 analog to digital converter. The whole system is powered by a 9V power supply. It includes a stepper motor to control the primary and secondary vents. The circuit chamber is water proof to avoid the damages due to accidents. This was required because kitchens are usually moist and damp.

3.6 Software Unit. The main task of software unit of ***Batho Chulho*** is to act as a middleman to process, user input and sensor data smartly to effectively actuate different activities in the system.

In ***Batho Chulho*** software complexity is relatively less than hardware in terms of design perspective. However, actual implementation was little bit tedious as sixteen bit text based display compilers were to use which have less debugging features.

The UML diagrams were mainly used to model and implement the software unit. For explanation purpose the whole system is represented as a large class with all necessary data and functions, sequence diagram was used to model actual flow sequence. To determine the actual procedures activity diagram was constructed.

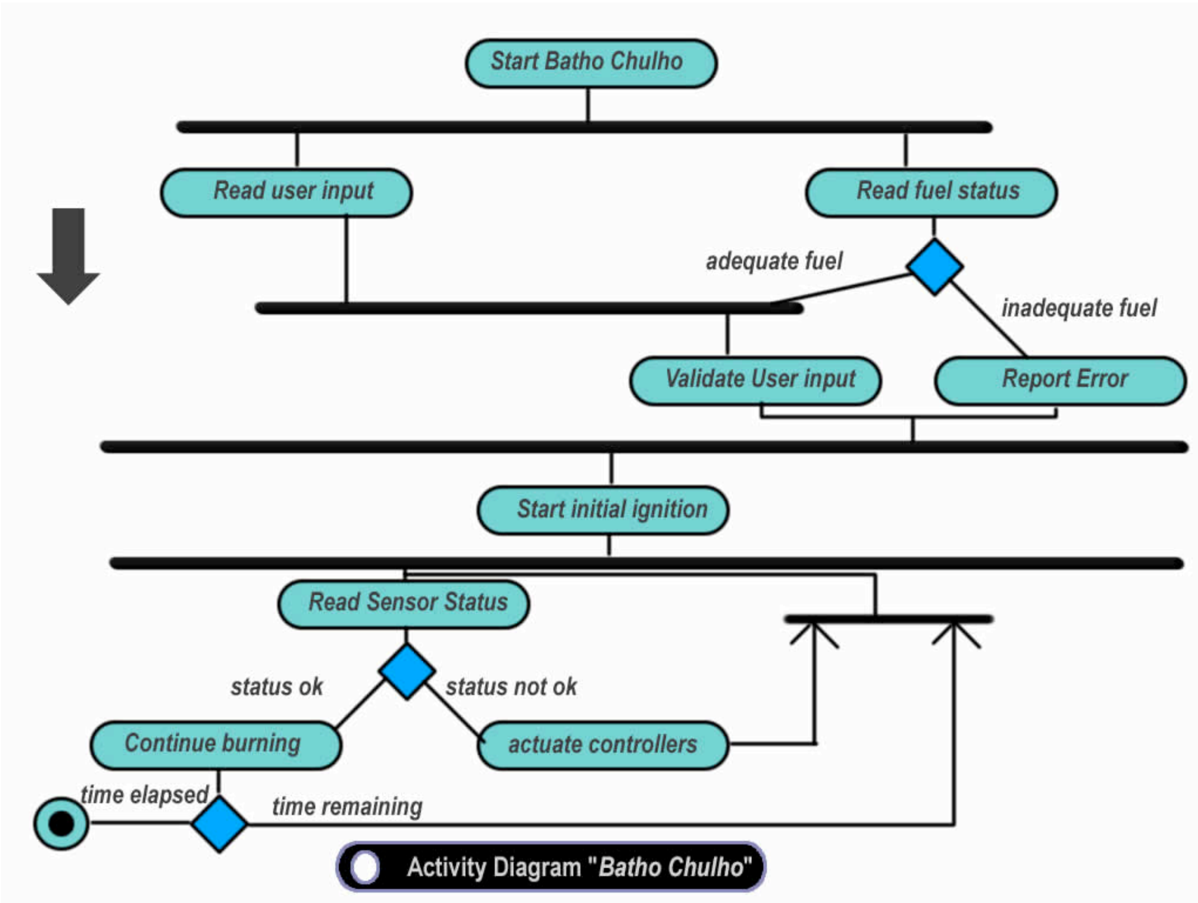

Fig 3.7: The Activity Diagram of *Batho Chulho*

3.6.1 *Batho Chulho* Class. The Class of the module is designed so compactly that the software and the related data should fit in the small memory of the microcontroller. But we haven't omitted any functionality required. The Class formation was also one of the most challenging tasks for the team. The basic elements, data variables and methods, of the ***Batho Chulho*** class are presented in class diagram below.

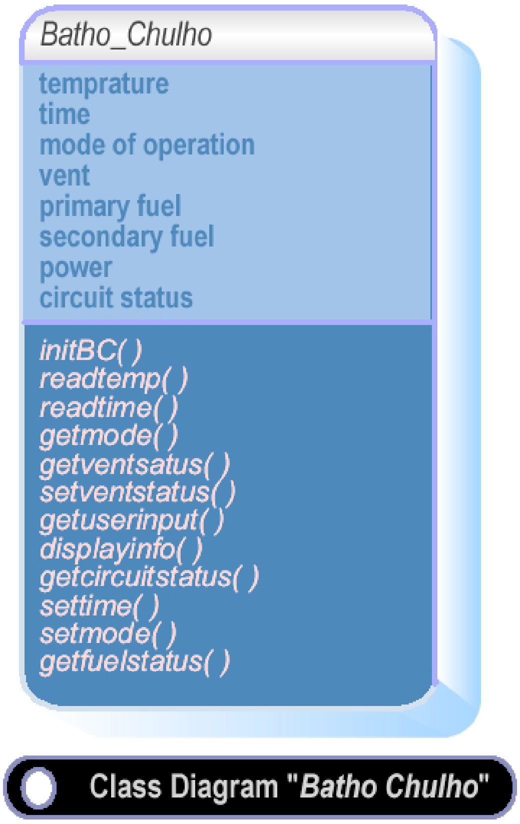

Fig 3.8: The Class Diagram of *Batho Chulho.*

The different entities are described in the following tables. The descriptions are more generalized to include the information required to use them.

Table 3.2: General Description of Variables of *Batho Chulho* Class.

S. No.	Variable Name	Description
1.	***Temperature***	Holds the temperature related information of the system.
2.	***Time***	Stores time related values of the system which includes uptime set by user.
3.	***Mode_of_operation***	Stores the operation mode set by user in the control panel.
4.	***Vent***	Store the status of the vent.
5.	***Primary_fuel***	Value to indicate the remaining briquette to be burnt.
6.	***Secondary_fuel***	Value to indicate the level of the remaining igniter fuel, kerosene.
7.	***Power***	Stores information about battery power.
8.	***Circuit Status***	Stores Boolean value for circuit status.

Table 3.3: General Description of Methods of *Batho Chulho* Class.

S. No.	Method Name	Description
1.	***initBC***	**Initializes the *Batho Chulho* system.**
2.	***readtemp***	**Gets current temperature value from the sensor.**
3.	***readtime***	**Reads current time from the timer and find the difference of the time set by settime method.**
4.	***getmode***	**Read the mode knob position to find out the user's mode of operation.**
5.	***getventstatus***	**Reads the current vent status.**
6.	***setventstatus***	**Sets the vent to required position calculated by the software.**
7.	***getuserinput***	**Scans the user input and assign the corresponding data in the respective variables.**
8.	***displayinfo***	**Displays the information in the LCD screen.**
9.	***getcircuitstatus***	**Reads the current status of the circuit.**
10.	***settime***	**Sets the remaining time to turn off the system.**
11.	***setmode***	**Set the mode of operation according to the user input.**
12.	***getfuelstatus***	**Read the current status of the primary fuel and the ignition fuel.**

3.6.2 Software development tool. SDCC compiler was used to develop the entire software coding and Topview Simulator was used to simulate the program during development.

3.6.3 Fuzzy Control. Generally a well known fact is that fuzzy control is incorporated in real life problem as sophisticated means of control which gains a desired equilibrium through digital logic system known as fuzzy. It would be irrational here to explain the fuzzy logic and fuzzy sets, rather we can postulate some reason why we were lured towards fuzzy control implication and how did we really used it.

Rate of heat generation during the briquette burning was not constant even though the system was constrained through all other possible constants, well established fact for most of the stoves locally build with local technology. But, the other side of story was actually in our favor. The heat generation rate showed a pattern, if certain level of Constraint was forced (in our case amount of air through Vent) the heat generation rate could easily categorized to levels. And transition between them was sufficiently overlapped. And the use of stepper motor for air flow vent controlling provided us enough discrete levels to control the amount of heat control.

Now the question was why should we not use fuzzy control? So we used the rate of heat generation and Pot Base Temperature as feed back inputs. Immediately we divided the sets of inputs as

Cook mode = {close, shimmer, cook, fry}
Temp = {cold, warm, hot, vhot}

Where Cook mode depicted the rate of heat generation desired and Temp was simply a temperature feedback. We also divided the output in five level which were.

Control = {large positive, positive, zero, negative, large negative}

The output thus divided were simply the angle at which the stepper motor is to rotate the vent controller. We then followed simple IF/THEN rules to construct fuzzy program for controlling which stayed in tight loop sensing the temperature and current vent status and actuating the stepper motor as necessary. The program was written in C style coding suitable for programming a simple microcontroller.

3.6.4 Flow sequence of the program. When the user triggers the initBC method is invoked. After that control is ready to get the user input. Then the user sets the time and mode of the operation. Then control panel scans the status of fuel, and temperature form sensors. And then checks for the valid time and mode. If mode is close or time is zero the routine exits.

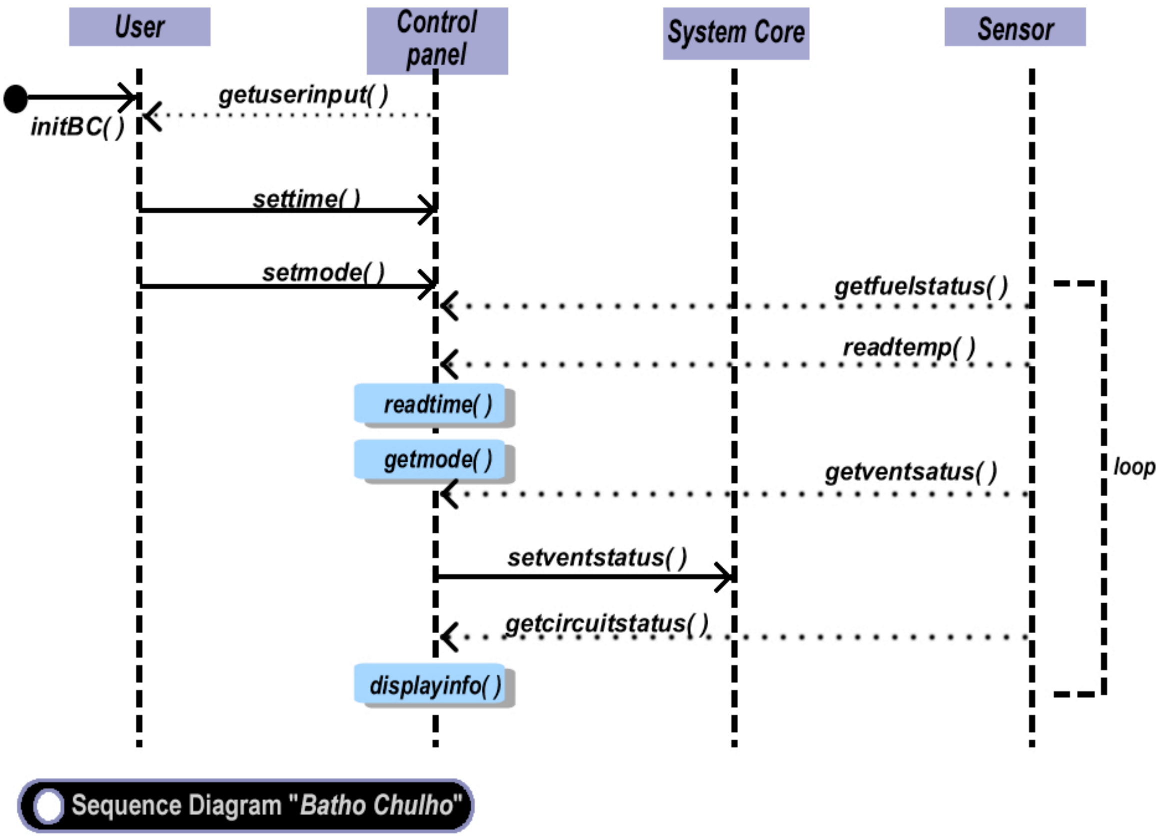

Fig 3.9: The Sequence Flow Diagram of *Batho Chulho.*

If everything is OK up to now, then the current vent status is read and the desired vent status is set. After finally checking the status of the circuit the display information are updated. And the system runs in the loop until the exit condition is satisfied.

3.7 Cost The cost of the project is tabulated below. The total cost seems so less but this is the actual cost rounded up. The cost needed to be less according to our design requirement since the product is targeted for the poorer ones. And the stove can be even constructed in less cost if some optional modules are not used.

Table 3.4: Cost of *Batho Chulho.*

Particulars	Cost in US$
Microcontroller(AT89C55)	**2.00**
Stove Prototype	**4.00**
Stepper Motor	**5.00**
Other Circuit Components	**4.00**
Ignition System	**3.00**
LCD Panel	**8.00**
Stove Hardwares	**3.00**
Battery	**1.50**
Development Cost	**4.00**
Misc	**3.00**
Total	37.50

And the running cost of the ***Batho Chulho*** is:

- $0.15 for a normal briquette which lasts for two cooking sessions of general Nepali family of 5 persons. But the cost is virtually $0.00 for those who make briquettes themselves, since it can be made easily.
- $1.50 for battery which generally lasts for about 2 months for average Nepali family.
- $1.00 for kerosene and igniting lighter which lasts for about 2 months.

3.8 Testing and Verification. As out system design was modular, we designed and tested each module separately. Then only we assembled them and tested finally. Here we show some final test results, which proved the project as successful.

The stove was tested in two modes, Frying and Shimmering mode for ***Batho Chulho***. And the same test was carried for traditional stoves. The test results are drawn in the chart below. The efficiency were calculated using standard water boiling test formula. The formula is:

Efficiency (%) =

$$\frac{\begin{array}{l}(\text{Initial mass of water} \times \text{spec. heat of water } (4.2\text{kJ/kg. K})) \times \\ (\text{Boiling temp. of water (K)} - \text{Initial temp of water (K)}) + \\ (\text{Mass of evaporated water} \times \text{Latent heat of water } (2257 \text{ kJ/kg}))\end{array}}{\text{Mass of fuel used (kg)} \times \text{Calorific value of the fuel (kJ/kg)}}$$

The test result for the ***Batho Chulho***:

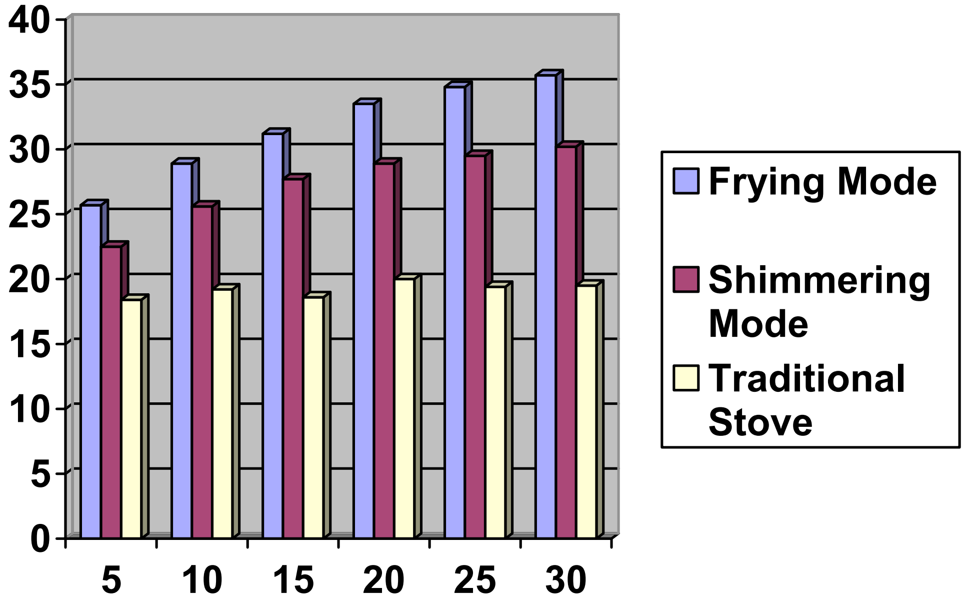

Fig 3.10 Time (Minute) vs. Efficiency (%) Chart for *Batho Chulho* and Traditional Stove.

The traditional stove was monitored for 30 min and found that efficiency was about 18-20 %. Time variable was not possible to vary because once burnt the briquette couldn't be stopped in the traditional stoves.

Note: All of the above data were accounted discarding initial ignition and final stopping time.

The test results of the system are summarized as:

1. The efficiency of the briquette was found to be increased to about 30-35% in place of 18-20% in older prototypes.
2. The system ran properly for most of the runs with some adjustable and ignorable errors.
3. The auto ignition system has not been full proof yet.
4. The metal casing was noticeably warm after the burning which is not required.
5. The life expectancy of battery was found to be acceptable.
6. The initial burning time has not yet been stabilized.

3.9 System Design Trade-offs

During our design we were buried with the trade-offs we needed to make so that the system achieves its goals. Some of them worth mentioning are:

1. Since we needed to design the system for the communities without electrical power supply, we could not put more electrical components.

2. The standard size of the briquette was larger to make auto feed mechanism and smaller to make stove work for long time.

3.10 Team. Before diving in the ocean of work ahead, we thought it would be better to discuss and subdivide the team so each could get fair share of job. We placed the mentor at top of the tree as we all could access him practically without engaging him randomly. Beside mentor also had to conduct Formal Technical Reviews time and again and collect appointments and inspirations for us to get around.

We carefully examined interest and work done prior of each member and found that our interest perfectly fitted together in some aspects and drastically differed in others which may have been due to diversity in faculty and limited knowledge horizon. Finally we constructed fine woven team structure. Our effort didn't go into vain. Team was productive as the interconnection between the subdivided teams was strong. Beside that we agreed upon to have a weekly progress meeting in which the result from Formal Technical Review was analyzed and tallied upon with separate progress report of team. We also extend our gratitude to Internet Conferencing which helped us a lot in our report preparation and finalization phase as road outside was hot with ongoing political crisis and severe security measures were being followed. Internet kept our team spirit alive as we shared and discussed the whole report among ourselves being online. At arriving at the end of our work we were even called "boring quads" by some of our pals.

4. Summary

4.1 Conclusion. The implementation of the project clearly revealed the fact that by using computational control techniques, the cooking-efficiency of a cook-stove can be greatly improved. The feature of the system is not just the improvement in the cooking efficiency but also the ease-of use features that makes it much more accepted in rural communities where other improved cook-stoves are not quite popular. The contribution in environmental preservation is therefore achieved at two levels. Firstly, with smart control of the cook-stove, the fuel is efficiently utilized, thereby saving the fuel. Secondly, the ease-of-use features integrated in the system attract more users to abandon their traditional inefficient cooking techniques and adopt more fuel efficient and less air polluting technique. With more than half of the world population as the potential user, ***Batho Chulho*** can play a significant role in protection and preservation of the environment.

Apart from the direct benefits to the society in terms of environment protection and preservation, ***Batho Chulho*** also benefits the end user in three different ways. Firstly, as the cooking is more efficient, the cost of cooking will be less as compared to existing cook-stoves. The reduction in fuel consumption is such that the initial cost of the system will be paid-back within a year of investment. Secondly, ***Batho Chulho*** uses the briquette as fuel and therefore the pollution in the kitchen is minimized. Indoor pollution is considered to be a major cause of health problems in developing world and hence ***Batho Chulho*** helps to reduce health hazards due to pollution. Lastly, the ***Batho Chulho*** system is designed such that it requires very little attention during cooking and therefore the end users can allocate more time to other productive jobs.

Batho Chulho utilizes locally available renewable fuel, is easy to operate, and is customizable according to budget and availability of the resources. This versatility provides *Batho Chulho* a potential to gain popularity among the rural community worldwide.

4.2 Further Work. During the development of the project, we very well realized the fact that we had propounded a field in which a lot can be done. The principal feature of the project is its requirement for localization. As we target to replace all wood-fire cook-stoves with ***Batho Chulho,*** we need to localize our system components accordingly. The present work does not address the localization issue to the required degree. For example, in a place where electricity is not readily available, we need to work-out appropriate source of electricity. It could either be solar powered cells or batteries or hand generators. Similarly, localization of the user interaction also needs to be addressed. We also plan to come up with an indigenous ignition system so that kerosene, which is not widely available, is not required for initial ignition.

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